LENSES—IN USE

A practical guide to the choice and use of lenses for different branches of photographic work, giving the vital facts about the different types of lenses and their special advantages in use.

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Lenses—in Use

The first step in all photography is, or should be, the selection of the proper equipment for the work to be done. Equipment here means the camera and lens, with the emphasis on the lens—as it should be. It is the lens which gives the picture. The camera is simply a dark chamber (*camera obscura*) in which the lens projects the picture-image onto the sensitive plate, which occupies the back wall, so to speak, of the camera. But, despite this vital importance of the lens, the camera with its accessories and the sensitive material used have a more powerful influence on the quality of the work done by the lens than is generally appreciated. Lack of appreciation of these factors often minimizes lens qualities and advantages. With a practical knowledge of his apparatus and materials and their relation to the lens, the photographer can produce good work even with indifferent tools. But the best results will be secured, with greater certainty and convenience, in proportion to the quality and adjustment of the equipment, and especially in proportion to the user's knowledge of the capacities and limitations of the lens. For which reason the reader is urged, here, in the beginning, to make sure that his equipment, in design and adjustment, can and will enable him to use his lenses to the limit of their capacity.

First a word about the work done by the lens, its function in making the photograph. This is the formation or projection of an image, on the sensitive film in the camera, of the objects in front of the camera at the time of photographing. How does the lens form or project the image? Let us consider all visible things as bodies whose surfaces are made up of an infinite number of luminous points, with every point reflecting light-rays in all directions. These light-rays, proceeding from every point in the object, bear images of the points from which they are reflected. When we look at any object, the eye intercepts or collects a number of these image-bearing rays, condenses them to points again or brings them to a focus and re-arranges them upon the retina, thus projecting an image of the external object within the eye, each point making up this picture-image being a counterpart of a corresponding point in the object.

"Pinhole" Images. If we set up a camera, with a focusing screen, facing any well-lighted object out of doors and, in place of the lens on the front of the camera, fix a shield of thin metal or card pierced at its center with a needle (thus forming a needle aperture or "pinhole"), we will get on the focusing screen a true, though inverted image of the objects in front of the camera. It is thus possible to make photographs with a "pinhole"—without a lens. The "pinhole" image, however, is nowhere sharply defined in form and detail, and is so feebly illuminated that a very long exposure is required to impress the picture-image on the sensitive film. The "pinhole," then, is useless for any sort of photographic work where sharp definition and short exposures are essential.

Lens Images. If now we replace the "pinhole" on the camera front with a simple converging (positive) lens, and rack the camera front in and out (from and to the subject), we will get on the focusing screen a picture-image in part at least well defined, and much more brilliantly illuminated than the "pinhole" image, so that we can impress this image on the sensitive film in a fraction of the time (exposure) required by the "pinhole."

This capacity of the lens to bend or converge the image-bearing rays to points, thus giving a sharply defined image, is known as its defining power. The image so formed is projected in an aerial field behind the lens, commonly called the image plane or focal plane. In photographing, the sensitive film is placed at or within this image plane. The light-transmitting capacity of the lens constitutes its rapidity. The quality of a photographic lens depends on its defining power, i. e. its capacity to bring to points, over a large field or area, the image-bearing rays which it transmits. The rapidity or speed of a lens depends on the volume of light-intensity brought to the image plane or the brightness of the image.

Simple Lenses are discs of glass with highly polished surfaces, at least one of which is curved or spherical in form. They are divided into two classes: positive or converging lenses, which bend the light-rays inward towards the axis of the lens (an imaginary line connecting the centers from which the two surfaces of a lens are struck); and negative or diverging lenses, which bend the rays outward from the axis. There are six possible lens shapes, or seven if we include plano-plates, as follows: Double-convex, as in some view-finders, reading glasses and magnifiers; Double-concave, as in reducing glasses; Plano-concave, used in some direct view-finders; Meniscus lenses have both surface curves facing the same way, and are positive when thicker at the center (like a young moon), and negative when thinner at this point. When the surfaces are plane and parallel we have a plano-plate, as in ray filters. When this type of lens is ruled with a series of concentric circles of mathematical precision, we have a "zone plate," which has a lens action and will give images of a sort. A meniscus, very thin, with equal curves, becomes a "zero focus" lens, like a plano-plate, and has been turned to practical use as a supplementary in "soft-focus" work.

The simple lenses forming a combination or lens system are sometimes called members. Air spaces, separating simple lenses or combinations, are really lens members bounded by the adjacent glasses. Complete lenses or lens systems are also called objectives.

Lens Errors. Simple lenses, although giving an image superior to that given by a "pinhole" in definition and brightness, are defective in so many ways as to be incapable of meeting the requirements of photography. These defects and lack of capacity are due to the errors, aberrations and faults inherent to all lenses. By the combination of several simple lenses, made of glasses having different optical qualities and varying in surface curvatures, the optician has progressively balanced, reduced, minimized or eliminated these errors. Since, however, all existing lenses are not perfectly corrected, and even the perfectly corrected lenses of today represent compromise rather than finality, it will be useful to consider the principal lens errors and their correction before going further.

Chromatic Aberration is color error: the inability of the lens to converge a ray of white light reflected from a luminous point in the object to a corresponding point of white light in the image, due to the dispersion or separation by the lens of the several color-rays making up the white ray. The light rays which make up the focusing screen image are green and yellow rays, to which the eye is most sensitive. The blue and violet rays, which most strongly affect the sensitive film, come to a focus nearer the lens, and so give confusion circles on the sensitive film instead of points, with the result that a sharp picture can only be obtained on the film by moving the screen image out of the plane of visual focus. By using suitable kinds of glass and proper curves, the optician "achromatizes" the lens and so corrected it is said to be achromatic. Lenses corrected for three or more colors, needed in photo-engraving and color reproduction work, are described as apochromatic. All modern lenses, except a few of the "soft focus" type, are corrected so that the yellow (visual) and blue-violet (chemical or actinic) rays will meet in a precise point in the image plane. In such lenses the chemical and visual foci are said to be identical. It should not be overlooked that lenses may develop temporary chromatic error when used with artificial lights which vary widely from daylight.

Spherical Aberration proceeds from the form or shape of the lens. It is defined as the inability of the lens to bring to a precise point both the central and marginal rays of the same pencil of light. The rays passed by the marginal zones of the lens come to a different focus from the central rays, so that the image is a compound made up of various focus planes, without sharp definition. This error is corrected by variation of lens curves and the separation of lens members. It is also cured by the use of diaphragms, but this always means loss of speed. The difficulty of correcting this error increases rapidly when lenses are made of large diameter for speed, as in portrait lenses.

When oblique rays are considered, the error is known as zonal aberration or coma. Lenses having this defect do not have the same focus with all diaphragms, an obvious inconvenience in work where precise definition is required with the ability to pick up shadow detail. Point images show fuzzy outlines with a radial comet-like tail pointing outward on the edges of the field. Such a lens is apt to give grey, flat and veiled negatives with blunted image-points.

Curvature of Field. The inability of the lens to give a sharply defined image on a flat plane is due to the error known as curvature of field. All lenses except anastigmats have this error, hence anastigmats are said to have "a flat field," valuable in copying or photographing objects in low relief or lying in one plane. It can be partially corrected by the use of smaller stops.

Distortion. This is due to the varying thickness of the lens and is its inability to reproduce straight lines in the object as straight lines in the photograph. This error exists in all "single" lenses and varies in kind according to the position of the diaphragm, giving barrel-shaped lines when the diaphragm is in front of the lens and pincushion shaped lines when the diaphragm is behind the lens. Lenses having this defect are useless for architecture or copying. Lenses corrected for distortion, reproducing straight lines as straight lines are described as "rectilinear" lenses. This form of distortion cannot be cured by the use of smaller stops.

Astigmatism. This is the inability of the lens to give at or near the margins of the field an image of an object containing vertical and horizontal lines in which both lines are sharply defined at the same time. Lenses corrected for this error are said to be anastigmatic and will reproduce marginal points in an object as points in the image. Apart from this correction, anastigmats are usually thoroughly corrected as to the other errors or aberrations, so that the anastigmat can be depended upon to give a sharply defined image, with a perfectly flat field within a comparatively large angle when used at a large aperture. This degree of correction and perfection explains the higher prices asked for anastigmats as compared with other lenses. Because of its perfect correction and delicately adjusted qualities, however, the anastigmat calls for more careful handling and adjustment of the camera than is required with less perfected types of lenses.

Flare-Spot. All lenses have a flare-spot, but in lens designing the spot is spread over a large area so that it is harmless. When visible it is usually a patch of haze in the center of the negative or on the side of the plate opposite the image of a light object. A slight change in conditions of viewpoint or angle will generally eliminate flare-spot. Night photographs with bright lights included, reflections from sun on window panes, photographing against windows or a bright light, etc. are the extraordinary conditions producing flare-spot. Sometimes in using large aperture lenses which are stopped down this defect will show on white draperies. Similarly when using lenses with the front cell removed a reflection from exposed screw-threads or diaphragm edges may result in flare-spot. Often a pinhole in camera bellows or a leak in the lens front will throw an image on the plate which may be mistaken for ghost or flare-spot.

Lens Terms. A brief definition of some lens terms relating to the properties of lenses will be useful as helping to a better understanding of later pages. A "single" lens is one with two or more glasses cemented together in optical contact. Such lenses are usually achromatic but, except in the case of anastigmatic singles, are not rectilinear. A "doublet" consists of two such "single" lenses with a diaphragm placed between them. Doublets are usually corrected for achromatic and spherical aberration and distortion so that they are said to be "rectilinear." If each element or "single" lens in the doublet is of similar construction and the same focal length the doublet is said to be "symmetrical." If the elements differ in focal length, the lens is said to be unsymmetrical. Anachromatic means "non-achromatic," not corrected for color; such lenses give very softly defined images. "Aplanat": a lens corrected for chromatic and spherical aberration, working at a fairly large aperture, without distortion. The axis of a lens is the line connecting the centers from which the two surfaces of a lens are struck. Focus: this word is often loosely used as an abbreviation of focal length. It is the point at which the light rays passing through a lens are converged or brought together to a point. Front and rear combinations are the front and back halves or elements of a compound lens or doublet. Full Aperture: the largest diaphragm or stop with which the lens is fitted. Infinity: A great distance as compared with the focal length of a lens, from two hundred to five hundred times the focal length. The "intensity" of a lens is the maximum speed as indicated by the largest diaphragm aperture fitted to it. Lens mount, tube, barrel or focusing jacket are different names for the metal mounting which carries the lens glasses. Sometimes they are dispensed with entirely and the lens elements are mounted directly in the exposure shutter. Nodal points of admission and emergence are imaginary points in or near a lens, in reference to which the correction of a lens may be traced on the basis that all rays pass out from one point as though they had entered at the other; sometimes called "Gauss points" or "principal points."

Focus and Focal Length. These are two lens terms with separate and distinct meanings, though very generally used to express one and the same thing. "Focus" is really the point behind the lens in which parallel rays, i. e. rays coming from a very distant object, meet after passing though the lens. This is properly called the "principal focus" of the lens. The focal length of a lens is the difference or distance between the principal focus and another point in or near the lens when a distant object is sharply focused.

Scale. The focal length of the lens determines the size or scale of the picture-image. At the same object distance (the distance from the lens of the object photographed) all lenses of the same focal length give images of the same size. The longer the focal length of the lens, the larger is the image. If the object is very distant, the size of the image is proportional to the focal length of the lens used. Thus, if a lens of 6-in. focal length renders a distant house 1 inch high on the focusing screen, a lens of 12-in. focal length will give an image of the house 2 inches high, from the same standpoint. This rule does not apply in photographing objects comparatively near the camera. Increase in focal length means more weight and bulk in the lens if the speed remains constant, and necessitates increased bellows extension capacity in the camera, as the camera extension must always exceed the focal length of the lens, except in the case of certain telephoto lenses to be referred to later.

In measuring the focal length of the lens, you measure from an imaginary point (the back nodal point or so-called optical center or "focal center") which is often but not always near the diaphragm plane, to the image of a distant object in sharp focus on the focusing screen of the camera. If the image so obtained is the same size as the image which a thin, simple lens would give at precisely the same distance from the screen, your lens has the same focus or equivalent focal length, hence the term "equivalent focus" which simply means "focal length" or "focus" of the lens.

Finding Focal Length. While the focal length of a lens is really measured from an imaginary point, we need not bother with the exact position of this point, as we can find the focal length indirectly by the conjugate focus relations. Thus the difference between distance focus and that focus which gives an image of the same size as the object is practically the focal length of the lens. First focus the lens on a very distant object and then on a scale, getting an image of the latter of the same size as the original; the distance through which the lens must be moved from one position to another gives the focal length. The simplest plan is to use a long bellows camera and mark the two extensions on the bed, the distance between the marks giving the equivalent focus of the lens.

Conjugate Foci. Since the rays reaching the lens from a very distant object are parallel rays, the image of a distant object is sharply focused at the principal focus of the lens. Images of objects at different distances from the camera, however, necessarily come to a focus at different distances from the lens. Thus for every distance between lens and object there is a corresponding distance between the lens and the image. These two distances (image distance and object distance) are interdependent—as one increases the other decreases—and are known as the conjugate foci or conjugate focal lengths. When the object distance is infinitely great, the other conjugate, i. e. the distance between lens and plate is the equivalent focus of the lens.

Using Conjugate Foci. As the conjugates are the basis of all enlarging and reducing calculations, it will be useful to know how to find them in an emergency. This can be done by using the following simple formula: $F = (r + 1)\,p$ and $f = \frac{F}{r}$. Here F stands for the greater conjugate focal length; f for the smaller conjugate; p is the equivalent focal length of the lens you wish to figure and r denotes the ratio of reduction or enlargement. Ratio 4 means four times linear enlargement; using ¼ as ratio gives a reduced size image, ¼ linear reduction. It is simpler to treat r as a whole number and apply the value found according to the nature of the problem. It is obviously lens to object distance in reducing and ordinary photography, and lens to paper distance in enlarging.

For example for a reduction of 4 (¼ size) with a lens of 8 inches focal length, we have 4 increased by 1, or 5; multiply by 8 and we get 40 inches—the lens to object distance. Divide 40 by 4 and get 10 inches—the lens to plate distance. For an enlargement of 4 times linear, 40 inches would be the lens to paper distance and 10 inches the lens to negative distance. Note that the smaller conjugate is always r times the greater conjugate, e. g. $10 \times 4 = 40$. In copying same size, the ratio is 1 and the formula would read $(1 + 1)8 = 16$ inches extension and $16 \div 1$ or 16 inches lens to copy distance. As the distances are really measured from optical points in the lens, which are somewhat separated, these equal distances (two focal lengths at both sides of the lens) the total distance from the object to plate is not the same as four focal lengths. It should also be noted that the conjugate relations are modified by the use of filters, and by reversing prisms used in photo-engraving and with commercial copying machines. Conjugate foci tables may be found in any issue of the *British Journal Almanac* and many trade booklets on lenses or enlarging by those who do not care to get the figures for themselves by the formula above given.

As exposure values are based on ratios between diaphragm apertures and focal length, the conjugates must be considered in place of equivalent focal length in figuring exposures in copying and enlarging. Tables giving the required exposures with these variations are available in the yearbooks and in THE PHOTO-MINIATURE: No. 140.

Back Focus, a term sometimes used in lens catalogues, is the distance between the rear surface of a lens to the image when the lens is focused on a distant object. It indicates the minimum extension of camera or bellows required by the lens in use. In some lenses, e. g. the single elements of some Convertibles, back focus is greater than equivalent focus. This has the effect of adding to bellows extension, often advantageous in permitting the use of a shorter focal length with cameras of limited bellows extension, such as reflecting mirror cameras. In such cases the back focus of the lens controls lens fittings. Due allowance must always be made for the projection of the rear cell mounting of the lens used with reflecting cameras, so that the mirror swing clears the lens mount or you cannot focus on distant objects.

Extension Lenses, i. e. special lens elements which, substituted for the normal front element of a doublet, increase the focal length of the complete lens, are furnished by a few lens makers, e. g. Aldis Duo and Trio which increase focal length twice and one-and-a-half times respectively, and the Zeiss Distar which is added to the Zeiss F:4.5 and F:6.3 lenses, extending focal length by 1/3, 2/3 and 3/3, requiring double extension bellows capacity in use.

Covering Power is the capacity of a lens to give a sharply defined image to the edges of the plate it is listed to cover, at its largest diaphragm aperture. The field illuminated by the lens is circular (the circle of illumination). Any plate whose diagonal is less than the diameter of the circle will be covered, but the quality of the definition within this area will differ in the different zones from center to margins, according to the design and corrections of the lens. If you study the performance of your lens on a large camera, you will note two zones or circles of definition: a large circle of fair definition enclosing a smaller circle of critical definition lying at the center of the field. The larger circle, known as the circle of available definition, is, with some lenses, as large as the circle of illumination. The inner circle is known as the circle of listed definition.

With anastigmats or lenses corrected for curvature of field and other errors which affect the definition of the image on a flat field, the circle of critical definition is, or should be, sufficiently large to cover the plate for which the lens is listed. It is desirable that it should be somewhat larger than this, so as to give a well defined image when the plate is off center, as when the rising or cross front movement is in use, or to permit the lens to be used, with a small stop, to cover a large plate. With some lenses, as you stop the lens down, the area of critical definition is extended beyond the circle of listed definition. With other lenses the circle of illumination shrinks or is cut down by the use of small diaphragms. This needs attention when you use a lens to cover a plate larger than that for which it is listed.

Generally it is an advantage if the lens has extra or reserved covering power as far as the circle of definition is concerned, but too large a circle of illumination is often disadvantageous as resulting in light scatter and flat or veiled negatives.

Flatness of Field. Normally the field of a lens is curved, that is the image points are not focused in a plane, but on a saucer-shaped surface concave side towards the lens, hence it is incapable of giving a flat image of a flat object. This defect, known as curvature of the field, is most evident in old lenses, and may be partially remedied by stopping the lens down, which means loss of rapidity. Modern anastigmats are corrected to give a well-defined image on a flat field at large apertures, which combination of corrections constitutes their superiority over the earlier types.

Angle of View is a term applying to lenses in use, and is measured between two lines drawn from the center of the diaphragm aperture to the vertical edges (base), or the ends of the diagonal, of the plate. It indicates the amount of view included by the lens. With a plate of given size, the longer the focus of the lens, the less the angle included in the negative, but the scale or image size is the same with lenses of the same focal length. Thus the angle at which a lens works fixes the "drawing" of the picture. Very narrow angles are those around 20°, medium angles around 30°, normal angles around 45° to 60°, wide angles 70° and extreme angles 90° or more. If the focal length of the plate is less than the diagonal or long side of the plate we have a wide angle; if less than the short way of the plate we get an extreme angle. To cover a plate sharply at a wide angle requires special design and construction in the lens, hence we have special lenses sold as wide angle lenses, but such a lens ceases to be a wide angle lens when used on a much smaller plate than that it is listed to cover. Many highly corrected lenses, such as anastigmats, can be used as wide angle lenses on plates larger than those for which they are listed if small stops are used. This means that the lenses have an extra large circle of definition with reserve illumination power.

With large available angle, e. g. the angle at the lens, embraced by the circle of available definition, you can cover a plate which is well off center by the use of sliding or cross front movement or swings. Long narrow panels or square shapes may be included by the same circle, e. g. a post card 3¼ x 5½ in. or a 4 x 5, or a panel 1 x 6 in. as they have the same diagonals. Illumination falls away with extreme wide angles; thus at 90° angle the corners of the plate receive only 25 per cent of the light reaching the central portion of the plate.

The angle of view included by any lens on any given plate can be seen at a glance in Woodman's Table of View Angles, as given in any yearbook, or by the chart by Julius Martin on page 64 of THE PHOTO-MINIATURE: No. 134.

Diaphragm, Aperture, Stop all mean the same thing in speaking of lenses in use. Properly, the diaphragm is a thin plate, usually of metal though any opaque material will serve, with an opening or hole in it, generally circular in shape though for special purposes other shapes are employed, placed between the elements of double or compound lenses, or in front of the lens in the case of single lenses. Since the largest available diaphragm aperture is always smaller than the full open area of the lens itself, the diaphragm serves to "stop" a certain amount of the light which would otherwise pass through the margins of the lens—hence the familiar name, "stop."

Old lenses and some modern lenses used by process engravers have loose or separate diaphragms, known by the name of their inventor as "Waterhouse stops," which fit into a slot in the lens barrel or tube so that the aperture lies across the axis of the lens. In other old lenses a series of apertures of different sizes are arranged on a circular plate which rotates in the lens tube, so that each aperture can be brought into position at the center of the lens as required in use. These are called rotating stops. The most general form, however, is the "iris diaphragm," which consists of a series of thin metal or hard-rubber plates (leaves or segments) within the lens barrel or mount, which open from and close to the center of the lens like the iris of the eye, thus providing a graded series of apertures.

The Purpose of the Diaphragm is twofold: first, to improve the performance or efficiency of the lens in the projection of the picture-image; and to control or regulate the speed or rapidity of the lens in so far as this depends on the amount of light passing through the lens to the sensitive film.

Improving the Lens Action. Very briefly put, the use of the diaphragm improves the general performance of the lens by narrowing the cone of light-rays passing through the lens, so that the picture-image is projected chiefly by those rays which pass through the center of the lens. This directly increases the efficiency of the lens, and minimizes many of the defects which result from the errors or aberrations inherent in all lenses. Thus "stopping down" the lens by means of diaphragm apertures decreasing in size increases the "depth of focus" or depth of field, i. e. brings objects lying in different planes (at different distances away from the camera) to a reasonably sharp focus in the picture-image. Similarly the use of the diaphragm extends the normally small or restricted area or circle of definition from the center outward to the margins of the plate or sensitive film; gives greater evenness of illumination over the field of definition on the plate; minimizes the blurred or foggy outlines or zones resulting from chromatic or spherical aberration; and reduces the curvature of field and astigmatism existing in the lens. Of course, in anastigmats or highly corrected lenses, where these errors are practically eliminated or corrected by other means, the diaphragm does not play so large a part as formerly in the improvement of the lens action. But even with the most highly corrected lenses the usefulness of the diaphragm as a means of securing "depth" remains unimpaired, the amount of depth secured increasing as the size of the aperture decreases. Obviously the "stopping down" of the lens means a loss of speed or rapidity since the smaller the aperture the less the volume of light passing through the lens.

Diaphragms and Rapidity. The term speed, as applied to lenses in use, refers to the intensity of the light action on the sensitive plate or film. This depends on two factors: the volume of light passing through the lens, and the concentration or intensity of the light when it reaches the sensitive film. The first depends on the size (area, not diameter) of the diaphragm aperture and, as the areas of circles are proportional to the squares of their diameters, varies directly as the squares of the diameter of the apertures. As to the second: the light possesses a certain intensity at the diaphragm aperture, and this diminishes in proportion to the square of the distance between the lens and the sensitive plate. Putting these facts together we get a figure—the ratio of the square of the diameter of the aperture to the square of the focal length of the lens—which will express the relative speed or rapidity of the lens at the different apertures provided by the diaphragm system fitted to it by the maker, and at the same time give us a convenient guide to the exposures required with the different apertures.

Diaphragm Markings or Numbers. At first diaphragm apertures were arbitrary as to size, and were generally marked 1, 2, 3, 4, etc. from the largest to the smallest. As photography developed different systems of grading and marking apertures were introduced by different lens makers, with some resultant confusion. Of these different systems, the two most generally used with the lenses of today will be briefly described, viz. the F system and the U. S. system.

The F or f/ System. This does not, as some think, mean the "factorial" system, which term applies to a time method for developing negatives, but is the name of the simplest and most widely employed method of adjusting and marking diaphragm apertures—the "focal aperture" system.

In this method the different apertures are marked with fractional numbers directly indicating the ratio of the stop diameter to the focal length of the lens, the effective aperture (the apparent diameter of the aperture as magnified by the front lens) and not the actual diameter being used in this figuring. The series begins with the largest aperture, and is so arranged that each succeeding (smaller) aperture requires double the exposure required with the preceding (larger) aperture or half the exposure required with the next following (smaller) aperture. Thus, supposing the largest aperture has a diameter equal to one-quarter of the focal length of the lens, it is marked F:4 (or f/4). In this way we get a series of diaphragm apertures arranged as follows: F: or f/ number. 4. 5.6 8. 11.3 16. 22.6 32. in which the exposure is doubled with each succeeding (smaller) aperture.

The U. S. System. This means "Uniform System," not United States system as some suppose. It was devised by the Royal Photographic Society and, though officially discarded, is still found on some lenses. This method arranges the diaphragms in the same order as that given above but, beginning with the largest aperture known when the system was introduced, viz. F:4, this was adopted as a unit and marked No. 1, the succeeding (smaller) apertures being marked with numbers which directly indicated the increase in exposure required with each aperture as compared with that immediately preceding it. Thus F.5.6 was marked U. S. No. 2, requiring twice the exposure required by U. S. No. 1. F:8 was marked U. S. No. 4, requiring four times the exposure required by U. S. No. 1 and twice the exposure required by U. S. No. 2, the series running from U. S. No. 1 to U. S. No. 64. The following table shows the two systems at a glance, with the relative exposures required at the different apertures as above explained:

F: Numbers	4.	5.6	8.	11.3	16.	22.6	32.
U. S. Numbers	1	2	4	8	16	32	64
Relative Exposures	1	2	4	8	16	32	64

The F: or f/ values of the upper row have the corresponding exposure values given in the third line of the table, which exactly correspond to the U. S. Numbers in the second line. When F:8 is closed down to F:16, the diameter of the aperture is one-half but the area is only one-quarter and the exposure must therefore be four times as great. The fractional F numbers (eliminated in the U. S. System) come about from the necessity of providing apertures requiring double exposure, quadruple steps being too great. When tables are not available you can figure out any value or exposure as needed by the F: system by dividing the stop you intend to use by any stop for which the exposure is known and squaring the product. One second at F:11.3 is thus equivalent to four seconds at F:22.6. The rule is invariable. If one second were needed at F:22.6, dividing into F:11.3 will give one-half and one-half squared (one-quarter) times the F:22.6 exposure is the new exposure required—one-quarter second.

Identification and Changes. You can recognize the system employed with any lens by noting whether an F: or f/ or the figure 1 is engraved before the smallest figure on the diaphragm scale of your lens. To change from U. S. to F: or f/ values, multiply the U. S. number by 16 and take the square root of the product: 8 × 16 = 128 and the square root is 11.3 (F:11.3). To change F: or f/ values to U. S. numbers, square the F: value and divide by 16: 11.3 squared is 127.69 (128) and 1/16th of 128 is 8 (U. S. No. 8). Mistakes sometimes happen when the exposure figures for U. S. Nos. are used with lenses marked by the F: value system, as when changing from inexpensive hand cameras to one fitted with an anastigmat equipment. Similarly confusion arises from the fact that Continental lenses often bear aperture markings not given in the preceding table. The table following gives the equivalents for these irregular values:

F:	2.2	2.9	3.5	4.	4.5	4.8	5.	5.6	6.	6.3	6.8	7.
U.S.	.3	.5	.8	1.	1.3	1.4	1.6	2.	2.2	2.5	2.5	3.

F:	7.5	7.7	8.	9.	9.5	11.3	12.5	16.	18.	22.6	25.	32.
U.S.	3.5	3.7	4.	5.	5.6	8.	9.8	16.	20.	32.	39.	64.

Speed Ratings. The speed rating of a lens is indicated by the highest stop value (largest diaphragm aperture) at which it is intended to be used, a number or figure marked on the lens mount usually followed by the regular stop numbers in sequence. Thus F:6.3 is followed by F:8; F:11.3 and so on; F:4.5 by F:5.6; F:8; F:11.3 etc. F:6.3 has no place because it does not belong to the standard F: system based on F:4 as unit. Hence the speed rating number, which indicates the maximum rapidity of the lens, does not necessarily bear a regular relation to the other stop numbers. F:6.3, for example, is only sixty per cent faster than F:8 which, in turn, is twice as fast as F:11.3. Properly, when a lens is listed at F:4.5, this is a claim that it will give a sharply defined image from corner to corner of a plate of given size at that aperture. Some lenses will not do this unless a smaller diaphragm is used, so that comparison is not always as simple as it looks. On portrait lenses speed ratings always have a loose meaning as the definition at stated aperture falls away very quickly, and they generally have to be stopped down to give fair definition over a field of reasonable area. Some rectilinear lenses listed as working at F:8 do not measure up to the speed claimed when corner and central definition is a requirement. It should be remembered, however, that extremely large apertures (excess speed) are obtainable only by some sacrifice of either definition or covering power or both. Thus some anastigmats of extreme speed are restricted as to defining and covering power to the more central parts of the plate sizes for which they are listed, and cannot be effectively used in other than the mountings provided by the maker for the special uses for which the lens was originally designed. For example, an attempt was made to use an F:3 lens of 3-in. focal length (designed and mounted for cinematography) on a camera taking films 1 3/4 x 2 5/16 in. the lens being remounted in a between-lens shutter. So used the limitation as to covering power was plainly evident and the effort to increase the area of sharp definition by the use oi smaller apertures resulted in cutting down the illumination circle so far that the corners were not covered at all.

When F: Numbers Mislead. The F: numbers marked on the diaphragm scale do not correctly indicate the speed of the lens and exposure under all conditions, but only when the lens to plate distance is normal or practically at the focal length of the lens, as in photographing distant objects. According to the rule that the intensity of the light action at the plate varies as the square of the distance between lens and plate, so the aperture ratio and exposure change as this distance changes. Thus in copying same size, the lens to plate distance is double the focal length of the lens and the F: numbers marked on the lens for normal use should be doubled, F:8 becoming F:16 etc. The exposures would, of course, vary accordingly. Similarly, in photographing a nearby object, an F:4 lens of 6-in. focal length may require a camera extension of 9 inches. In this case the actual value of the aperture marked F:4 becomes F:6 $\left(\frac{4 \times 9}{6} = 6\right)$ and the exposure should be doubled. The practical rule here is to increase the exposure in the proportion of the square of the increased focal length to the square of the original focal length.

On the tube or scale of doublets whose single elements may be used separately, separate sets of markings are given for the aperture values for both singles and doublet. In such cases only do the apertures of the same number take identical exposures.

Diaphragm Defects. If we photograph an object having straight lines, such as a building, with a single lens having the diaphragm in front of the lens, all the straight lines near the edges of the picture will be bowed out (barrel-shaped). If the diaphragm is placed behind the lens, the lines will be bowed inwards (pincushion-shaped). This form of distortion results from the position of the diaphragm and cannot be remedied by stopping the lens down. As the distortion does not affect the image at the center of the plate, it may be disregarded as far as the use of single lenses for portraiture, landscape or views of distant buildings coming at the center of the field are concerned, but prohibits the use of single lenses in architectural work or copying. Similarly, this distortion does not occur with the single elements of convertible anastigmats, which are optically corrected for rectilinearity.

Depth of Focus. Probably more discussion centers around this term than about any other lens phrase. You will often hear a man say that this or that lens does not have good depth. "Depth of focus," as generally used, means the ability to bring to a satisfactory focus, or to get a sharply defined image of, objects situated at different distances from the lens. It is sometimes called "depth of definition" or "depth of field" (the preferable term) or "focal depth." Properly speaking, a lens has no depth of focus; that is a lens can only sharply focus objects lying in a single plane at one time. But in practice it is known that by using smaller diaphragm apertures or stopping down the lens, we can obtain depth of focus; that is we can increase the range of distance or depth in the subject within which all objects will be rendered agreeably sharp in the photograph.

Depth of focus, then, is dependent upon the relation between the focal length of the lens and the aperture in use. All lenses of the same focal length, used with a given stop or diaphragm aperture, have the same depth of field. Of two lenses of the same rapidity but differing in focal length, the lens of shorter focal length will have the greater depth of definition. This because the longer the focal length of the lens, the more marked are the differences in image planes. Of two lenses of the same focal length but different in rapidity the more rapid lens will apparently have less depth of field; but when stopped down to the same rapidity as the less rapid lens, the two lenses will have the same depth of field. It is sometimes said that great depth of focus is inconsistent with rapidity (i. e. large relative aperture) in a lens. But this all depends on the focal length of the lens in use. Thus a 3-in. lens even with an aperture of F:4.5, combines considerable depth with speed, but this is peculiar to lenses of very short focal length. As focal length decreases, depth increases, if the lens to image distance is constant. When lenses of different focal length are used at the same aperture, the lens of shorter focal length gives the greater depth. With lenses of the same focal length the use of smaller stops will give greater depth. With lenses of the same focal length and the same apertures, the distance away of the object being different in the two cases, the lens with the greater object distance will show the greater depth.

Flat objects have no depth of focus, so that stopping the lens down in copying can give no advantage except to minimize any errors or aberrations existing in the lens and so giving increased sharpness of definition.

By using a lens of short focal length and subsequently enlarging the image, you can secure an amount of depth quite impossible with lenses of longer focal length. This is a useful fact to remember when big images and great depth are required at the same time. Where only slight depth is needed, the large aperture of the long focus lens will give results which cannot be duplicated by enlargement of small images as suggested above.

Definition. As depth of focus concerns the obtaining of sharply defined images of objects at different distances from the camera, it may be worth while to consider what we mean by sharp definition. The optician's standard of definition is a "circle of confusion," sometimes called the disc of confusion, the diameter of which represents any point making up the picture-image projected by the lens on the screen or sensitive film. This disc or circle grows smaller as we stop the lens down by using smaller apertures. If the diameter of the circle of confusion does not exceed 1/100 of an inch the negative will have satisfactory definition when viewed at the normal reading distance. In making small negatives intended for subsequent enlargement, however, this standard of definition is inadequate and the circle of confusion should not exceed 1/250 of an inch. As this means stopping down the lens, the inevitable loss of rapidity must follow.

The depth advantages of small apertures can sometimes be turned to account to permit the use of a long focus lens as a shorter one. With a temporary stop about F:150, you can change the equivalent focal length of a lens in an emergency. Thus a 6-in. lens at F:150 will have a range of from 4 to 12 inches equivalent focus, useful where there is difficulty in getting the lens close enough to the plate for distant focus or in wide angle work.

All depth figures are based on ideal lenses, the practical effects of errors in the lens, the grain of the sensitive emulsion, etc., being ignored. These are sometimes quite considerably and rarely totally absent. It may be that the differences in depth claimed for different lenses of the same focal length and relative aperture are based on these differences in lens corrections, etc.

Hyperfocal Distance is a term much used in depth discussions and hand camera work. It is the distance beyond which everything will be in focus (or reasonably well defined in the picture) when the lens is sharply focused on an extremely distant object or infinity. It increases as the focal length of the lens increases and becomes smaller as the lens is stopped down.

The hyperfocal distance for any given lens and stop may be found by the simple formula: square of focal length multiplied by 100, expressed in inches, divided by 12 times the F: or f/ number, which gives the answer in feet. Thus with an 8-in. lens at F:16

$$\frac{100 \times 8 \times 8}{12 \times 16} = \frac{6400}{192} = 33 \text{ ft.}$$

In hand camera practice it is better to refocus on the hyperfocal point. This gives increased depth zone, the distance sharpness remaining unchanged, but the nearest object in focus advancing to a position one half of distance to hyperfocal point. Sometimes this "near point of satisfactory definition" is miscalled the hyperfocal point, causing confusion. Taking the example given above, if we refocus on 33 feet, using the same stop, the near depth of field limit will be 16½ feet from the camera.

For finer definition, as in small negatives intended for after enlargement, substitute 250 for the 100, which reduces the disc of confusion to 1/250-in. instead of 1/100 of an inch.

Fixed Focus, sometimes referred to as universal focus, is another term which puzzles the beginner. It simply means the use of a diaphragm aperture so small, with the lens fixed at a certain distance from the sensitive film, that fairly sharp definition of both near and distant objects will be secured in the picture. Lenses so fixed and "stopped down," as fitted to some inexpensive hand cameras, rarely work at greater speed than F:16, the lenses being usually less than 4 inches focal length, so that all objects more than 8 feet away from the camera will be sharply defined in the picture.

This, obviously, is only a practical use of the hyperfocal data already given, and the principle can be applied in the use of any focusing hand camera when this is convenient. Thus, in street views and out-door "snapshot" work generally, with a lens of 5-in. focal length and F:8, if we once correctly focus on an object 26 feet away, or set the focus scale mark at 25 feet, the camera will give us sharply defined pictures of all objects more than 15 feet away, so long as we use the lens at the same position and with the same stop.

Types of Lenses. Among simple lenses the positive *meniscus* gives the best images and such lenses are used on inexpensive fixed-focus cameras, being fixed at sharp position to compensate for lack of color correction. Their speed rating is low, F:16 and they work well only on small sizes.

The single achromatic lens has two or more members of suitable glasses and curves to correct color error. The section is usually of positive meniscus form, hence they are listed as *achromatic meniscus*. Old landscape lenses are of this type and give brilliant images, though not rectilinear. What we use today as single achromats are the half combinations of doublets, called "halves" or "singles." Their speed is usually around F:14, but with high correction may go as high as F:12.5, and still higher in the case of some F:4.5 and F:5.6 doublets.

Rapid rectilinears are doublets, usually made up of two opposing single achromats with the diaphragm between them, this construction eliminating the distortion of the singles. When the elements are equal in focal length the combination or complete lens is symmetrical, when these are unequal it is said to be unsymmetrical. Some rectilinears are convertible, i. e. you can use either one or both of the single elements separately or the complete lens at will, giving choice of focal length.

Anastigmats are perfected or corrected rectilinears, designed to give precise definition with freedom from distortion or error on a flat field at large apertures. Because of their higher efficiency, they are replacing the earlier rectilinear type for almost all purposes in photography. The greater their rapidity, the greater the care necessary in their fitting, adjustment and handling in use. As a rule moderate speed anastigmats have more reserve covering power and are more generally useful than those of extreme speed.

Portrait lenses are usually of the Petzval type in construction this giving a brilliant image within a restricted area with marked plane separation, producing roundness or relief in the image. Anastigmats are, however, largely used in portraiture today. *Pictorial lenses* are usually diffuse or soft-focus types, giving images generally soft in definition, due to lack of complete correction of chromatic and spherical aberration.

Telephoto lenses are either negative lens attachments for use with ordinary positive lenses, or complete lens systems, designed to give large images with relatively short bellows extensions, the size of the image varying according to the separation of the lenses. *Fixed-focus telephoto* means a lens of non-variable separation, giving only one magnification, focused in the ordinary way and used with cameras of short bellows capacity.

Condensing lenses (condensers) are used in enlarging. *Supplementary lenses* modify the focus of existing lenses to which they are attached. *Projection lenses* are types used in lantern slide and motion picture projection.

Air-space lenses are types in which the elements are not cemented, but separated by air spaces which, of themselves, serve as lens elements in the complete system. This type of construction does not necessarily mean that the lens is unsymmetrical. A *quartz lens* is a lens made up of quartz instead of optical glass, to gain speed by the transmission capacity of quartz for ultra-violet rays.

Convertible Lenses. With convertible types, you have the added facility of working with either the complete lens or the single element, giving two lenses in one, really three lenses, because when stopped down, the doublet is a wide angle lens on larger plates. The long focus lenses give larger images in proportion to their focal length but if plate size is not changed, the angle included is less.

Goerz Dagor F:6.8 is a typical lens. In the Dogmar, F:4.5, the elements are of unequal focal length, a triple convertible or hemisymmetrical type. In the Protar VII, the single lenses have four members and higher corrections. They can be combined to make two focus, F:6.3, VIIa Protars, or three focus lenses of F:7 or F:7.7 speed. Other two focus convertibles are the Collinear II, F:5.4, Collinear III, F:6.8, Amatar IX, F:6.8; Turner-Reich Series III, F:6.8; Hekla, F:6.8; Sylvar, F:6.8, etc.

In three-focus types are Velostigmat, Series II, F:6.3, Turner-Reich II, F:6.8, Stigmatic Series II, F:6, Ross Combinables, F:5.5, to F:6.3; Graf, F:4.5, F:6.3, and F:7.7.

The height of convenience is reached in convertible anastigmat sets. These have one mounting taking the single lenses or pairs as desired. They give great flexibility in operating, as you can use the focal length best adapted to your particular viewpoint. Some times there is no alternative viewpoint, but you can always find a suitable focal length among the possible combinations. Thus sets of Protar VII lenses give six different angles and sizes. With four singles, there are ten possible combinations. Pantar and Ross Combinables sets work similarly. In all cases, the doublets should obviously have the larger diameter single lens in the front.

On some imported sets, the diaphragm diameter is indicated on a millimetre scale and suitable tables of values are furnished. B. & L. Protar VIIa and Ross Combinables have a rotating ring, which when properly set will give values for each and any focal length.

In convertibles, the ratio of single lens focus to doublets is around 1 to 1½ to 2. Turner-Reich singles are 1¾ and 2⅓ times the focus of the doublet, hence their selection for panoramic work.

In the rapid rectilinears convertibles we have Versar, F:6, Voltas, F:8; Rapid Rectigraphic, F:8, Rapid Convertible, F:8. Perigraphic Convertible, F:5.6, Planatograph, F:8, Euryscope IVa, F:7, Ideal D.F:6, Dallmeyer F:8 and many others, some two focus and others triple convertibles.

The single elements of Protar VIIa and Pantar being highly corrected are very satisfactory at the larger apertures. They are not perfectly rectilinear. With single elements in general you are not concerned with covering power for large areas, as you will ordinarily use them for the same size negatives as the doublets themselves. Their back focus exceeds equivalent focus about 10 per cent when used in the correct optical position, with the diaphragm in front of lens. In practice, you can work them in the front position with very satisfactory results. It has the effect of adding bellows extension. While focus scale divisions are unaffected, the position of scale is nearer the image.

The general conclusion to be drawn from this brief survey of the lens, its errors and their correction, with its properties is that, for all around purposes one should choose (1) a perfectly corrected lens giving a sharply defined image over a flat field at a large aperture, (2) combining maximum rapidity and depth of focus capacity, and (3) capable of covering the plate in use sharply from center to corners, even when the lens is shifted from its normal position at the center of the plate by the use of the rising or cross front movement. This means (1) an anastigmat, (2) of the shortest focal length consistent with reasonable perspectives, (3) with ample covering power for the plate with which it is to be used.

Almost every different field of use, however, calls for specific properties in the lens advantageous in the particular field of use. In the following pages, therefore, we will consider the requirements of some branches of everyday photography and the available lenses best fitted to meet these special requirements.

Aerial Photography calls for only brief mention as far as lenses are concerned. Thoroughly good work was done in pre-war years, from balloons and kites, with ordinary apparatus equipped with lenses of great focal length compared with the plate sizes used. Examples may be seen in THE PHOTO-MINIATURE: No. 52, published in 1903. During the War airplane work and all branches of aviation photography received a great impetus. Anti-aircraft guns forced photographic observers to high altitudes making necessary long focus lenses, some of them exceeding 40 in. in focal length. Peace work presents different conditions. The work is done chiefly at low altitudes. The obtaining ot good images is largely dependent upon the use of filters and sensitive materials to overcome difficulties arising from atmospheric conditions, haze, color contrasts, etc. Special camera construction and devices for compensating the errors introduced by the departure of lens axis from vertical position play an important part in the quality of the result. Since the lens is invariably used at its infinity focus the size of the image is directly proportional to the focal length of the lens, and inversely proportional to the altitude of viewpoint. As against the use of great focal length to obtain large images, it has been found desirable to use shorter focal length, getting smaller images for subsequent enlargement. Thus lenses of 8, 10, and 12 in. focal length, e. g. the Bausch and Lomb Series Ic, IIb, Tessars; Goerz Dogmar; Carl Zeiss Ic, and Cooke Aviar are widely used.

Airplane mapping has a broad field in survey work as an enormous labor saver in supplementing ordinary methods; also in commercial view and bird's-eye work, the photographing of estates, industrial plants, and the like. In some mapping cameras multiple lenses are used and the records are combined. Special devices are employed in photographing with motion picture cameras from airplanes, and in balloon photography fixed-focus telephoto anastigmats have been used with advantage.

Architecture. In this field we are concerned with the representation, on a flat surface, of three-dimensional objects, designed to produce a pre-determined effect when viewed in a chosen location, with straight or curved vertical and horizontal lines or forms as a characteristic feature. Obviously the problem is one best solved by stereoscopic or two-lens photography; but here we are dealing with everyday architectural work, using the ordinary one-lens camera and equipment.

Scale, perspective effects, accurate drawing and detail definition are the prime essentials. In the choice of lenses we must consider focal length, which, from a given viewpoint, controls the scale of the image and perspective effects; freedom from distortion (rectilinearity) as necessary for correct drawing; and view angle capacity with covering power, which have to do with wide-angle work when this is necessary, and limit the field of available definition and even illumination when the lens is shifted from its normal position at the center of the plate, as often happens in this class of work.

Because of the general difficulty of securing the ideal viewpoint, focal length is the vital factor. The common fault is forced or violent perspectives, due to the use of lenses of too short focal length, often necessitated by the restricted working space available.

Equipment. Three lenses of different focal lengths: the first slightly less than, the second one-and-a-half times, and the third two or two-and-a-half times the base or diagonal of the plate, may be regarded as the minimum equipment for the widely varying requirements of the field. Sometimes an "extreme angle" will be necessary, and a telephoto may be useful where the subject includes inaccessible detail, as in public buildings made for architects.

The lens equipment may consist of separate, complete lenses, rectilinears or anastigmats, or better, of the more compact convertibles or sets of the anastigmatic type.

Since short exposures are rarely called for in architectural work, except in difficult interiors and exteriors with nearby trees in foliage, and as all lenses must be stopped down for depth, good work can be done in this field with rectilinear lenses by reputable makers, which can often be picked up for a song. They are slow and limited in covering power, but extremely efficient if handled intelligently.

The more perfectly corrected anastigmat, with its excess covering power and greater angular capacity (permitting its use as a wide-angle on a large plate when stopped down) is, of course, the better investment, e. g. the Turner-Reich F:6.8; Tessar F:6.3; Serrac F:4.5; Velostigmat Series IV; Dagor F:6.8; Cooke F:5.6; Graf F:6.3 and Collinear F:7.7.

Especially advantageous because of the variety of focal lengths available in one instrument, are the convertibles, viz. Stigmatic F:6; Turner-Reich Series II; Velostigmat F:6.3; Graf F:6.3; and the Protar and Pantar sets, in which the single elements are corrected for distortion and astigmatism.

For special wide-angle work the Protar F:9; Turner-Reich F:18; Velostigmat F:12.5; and Primoplane F:6.5 are largely used. The Dagor F:6.8 also offers usefulness here because of its fine correction over an unusually extended field. For tall buildings or skyscrapers in confined situations, the Hypergon (maximum angle, without star diaphragm 110°) is the only lens available.

The telephoto needed for occasional work may be either a negative attachment fitted to the regular positive lens of short focal length, such as the Bausch & Lomb, Goerz, Carl Zeiss or Voigtlander telephoto attachments; or a complete lens of the variable or fixed-focus type, e. g. the Pancratic; Adon; Dallon; Magnar or Cooke Telephoto.

The fact that the camera and tripod largely influence the performance of the lens in architectural photography should not be overlooked. It is folly to invest in high-priced, highly-corrected lenses having special properties, and to lose in the results by the use of poor camera equipment. Lack of accurate adjustment, perfect rigidity and steadiness and any liability of vibration are fatal to success in this sort of work.

Color Photography. In the use of screen plate methods, the correction of the lens for red (apochromatism) is not as important as in color-separation or registration processes. The red records are always best when the red focus approaches the general focal plane and exposures are thus reduced. Speed is always an advantage, because of the loss of light incidental to the use of compensating filters, hence the advantage of lenses working at F:4.5. Flashlight color work demands special filters because of the differences in the actinic values of flashlight and daylight.

In screen plate work, when the filter is used at the back of the lens, this compensates for the reversal of the color plate in the holder and saves reversal of the ground-glass screen for focusing. Zeiss Ducar filters are designed to work in front of the lens and compensate focus displacement optically, as does the Graflex color plate holder. Around sunset the atmosphere acts as a filter; all the violet is gone at 8° sun elevation, but 55 per cent of the red still remains.

In color reproduction processes (separation work) the best results are obtained with apochromatic lenses, e. g. Goerz Artar; Zeiss Apochromatic Tessars; Collinear F:9; Cooke Series V and Va; Velostigmat Process Lens and Dallmeyer Series VIII, all less rapid than anastigmats not corrected for three-color work.

Commercial Work. Lens economy and lens efficiency, with a minimum of weight and bulk for carrying, point to the anastigmat sets Protar and Pantar as ideal for the infinitely varied requirements in this field. Next in usefulness come the convertible anastigmats, e. g. Protar VIIa, F:6.3—F:7.7; Dagor F:6.8; Turner-Reich Series II and III; Stigmatic F:6; Wollensak Series I; Graf F:6.3 and Collinear III, F:6.8. These provide appropriate focal lengths for any condition and rendering desired, except perhaps extreme wide-angle work, for which a special lens should be provided. The single combinations will rarely be used at full covering power, give brilliant images, and are very satisfactory in practice.

Where rapidity is not essential, rectilinears give very good results with ample focal lengths and small apertures. Cooke F:8 and Turner-Reich F:9 are good and moderate in price because of lower speed.

There are cases where perspective depth and size cannot be obtained simultaneously, as with large images of cut glass and deep silver bowls. In such cases, make a small negative getting the desired depth at proper perspective distance and from this make a large print by projection. This is better than seeking for the ideal long-focus depth-producing lens which does not exist.

For work requiring the inclusion of a large view angle a medium or extreme wide-angle lens must be used. For a choice of these see *Architecture*.

Copying. The best copies come with process lenses when there are fine lines to reproduce, but the rectilinear finds many applications. It should not be too short in focus nor worked to extreme covering power. Stopping down does not cure astigmatism and, for ability to pick up shadows, the anastigmat stands alone. The moderate speed types are used. For lenses primarily for copying, you can select F:8 or F:9 lenses used in commercial and photoengraving work, e. g. Gotar, F:8, Dallmeyer Process, Series IX, also longer focus wide angles like Protar V.

Too short a focus makes it harder to overcome reflections on glossy prints and paintings. With large originals, a long focus lens allows good working distance and does not force side lightings, which emphasize surface texture.

With artificial lighting in general, you should illuminate copies from both sides equally to get rid of surface grain. Glycerine on a print covered with glass has been used effectively. Color sensitive plates speed up copies with tungsten lamps which are rich in red rays. The use of filters for ortho effects is a chapter by itself and astonishing results may be obtained by proper technique.

Smaller stops tend to give flatter results and the best plan is to use the largest stop consistent with definition, especially on line subjects, which are usually best on slow plates. Focus critically and save stopping down. Large lenses stopped down give more equal illumination, because they intercept fewer marginal rays. Fine ground glass and focusing magnifiers are useful accessories. Accurate register of plate holders is quite necessary.

For full size copies, you can often use shorter focus lenses because you have really doubled the focus and covering power. The exposures vary with distance as noted under *conjugate focus*. You will learn to judge illumination on focusing screen although tables of stop changes and exposure figures can be obtained. Artificial lights are more constant in value than daylight and are very convenient. Chemical focus troubles from lights varying widely from daylight are mentioned under enlarging.

Paintings should not be inverted, as artists get shadow effects from brush marks, and these may change effect in the photograph because direction of lighting is changed.

View cameras or cameras with double extension, are convenient for coyping, and the simple portrait types for post card and penny picture work can be obtained very reasonably.

Enlarging. Lens selection depends on size of negative and available working distance. Enlargement size is governed by distances between lens, negative and paper. Your problem is to transfer a flat negative image to a flat easel. The less you stop down, the less exposure you need, an advantage on dense negatives. Moreover, long exposures are liable to suffer from vibration and irradiation, which is a species of halation or sidewise spreading of the image in the sensitive film.

Flat field anastigmats have advantages because you can work shorter focal lengths and reduce image distance. Moderate speed types are best as any of F:6.3 types mentioned for hand cameras, also the F:8 and F:9 lenses for commercial work. In using artificial light metal diaphragm leaves are sometimes necessary because of heat. You can often find rectilinears that serve very well of somewhat longer focus. Portrait types vignette on corners, but with large negatives they have some advantages.

The lens with which the original negative was made is often recommended. If its error is a drop in illumination at edges of field, such errors may be increased. Even with an ideal enlarging lens you cannot increase the negative quality. You may stop down, but you still have an optical record of the negative defects. Lenses can be specially corrected for enlarging, e. g. the lenses fitted to Kodak Projection Printers, and are valuable where there are many dense negatives. Such lenses do not need as much stopping down.

Definition can be softened by black chiffon cover over the lens or by various grades of bolting cloth near easel, or by soft focus lenses on sharp negatives. With old type Veritos, diffusing stops with radial openings gave diffusion control. The current Verito lenses do not require them. The finest effects, however, come from soft-focus negatives. In enlarging from sharp negatives it is better to work from positives, because the enveloping image from the soft-focus lens is then formed round the high lights as it should be. Diffusion on the Eastman Projection Printer is obtained by the Diffusing Disks with minute optically-worked corrugations, giving various degrees of softness.

Non-symmetrical lens types have a larger front glass diameter and are corrected for use with large lens facing object. In enlarging, the negative is really the object being photographed. Unqualified statements about reversing lenses are confusing, for when you put a lens on the ordinary enlarging apparatus in the natural way, it is facing correctly and a further reversal makes it wrong. When copying, enlarging and reducing cameras are used for direct enlargements, the kind where the lens goes in a central compartment, you have a choice and the lens boards are so devised that lens may face either way. You can always go straight on any type of apparatus by noting the longer distance, lens to subject in copying and lens to paper in enlarging, and then use the lens so that its larger glass or the cap end of the lens lies on the same side of the front board as the greater distance. In modern enlarging cameras, the bellows encloses the lens to object distance, just the reverse of ordinary conditions.

Condensers. Much enlarging is done with condensers or reflecting substitutes. The lenses are plano-convex, short in focus, with convex surfaces nearly touching. They collect light from the enlarging lamp and converge a cone of rays to fill the back glass of projecting lens. If the cone is too big or too small some light is wasted. The negative sets in the cone of light, near flat side of front condenser.

If the light is not properly adjusted, you get uneven illumination and shadows, which indicate the re-adjustment to make in light position. The cone should be central on the axis of the lens and while in theory it should meet at diaphragm, it has to be focused further front, due to lens aberrations. The nearer the light source approaches a point, the less trouble from unequal illumination and shadows, when lenses are stopped down. Conditions are somewhat different, however, with very large sources, like flaming arcs, or with inverted Welsbach mantles. It may be impossible to get a clear field on edges even when the light is centered, this indicating that lens focus does not suit condenser focus or vice versa, or that the lens has too small diameter. The best focal length is about 10 per cent greater than long side of plate. Such lenses work well with the condensers listed for sizes corresponding to sizes for which lenses themselves are listed. A 5 x 7 negative needs a 9-in. condenser, which works nicely with 7 or 8-in. 5 x 7 lenses on ordinary ratios of enlargement. For only slight enlargement or for reductions as in lantern slide making, a different focus lens or condenser may be required. In taking small heads from groups, a short focus lens of low quality may be used because of small angle required.

With 14-in. condensers, there is always trouble in getting a field without colored margins. Even 12 or 14-in. F:6.3 lenses may be too small. A large diameter lens, e. g. portrait or projection types, is needed. Such large lenses act as auxiliary condensers and change the angle of the cone of light. Restriction of lamp movement is a common error in apparatus. You need convenient adjustments up and down and crosswise and ample space for movement to and fro.

Condensers always have ripple marks or striae which may show up as shadows on the screen. Condensers should not be heated up too quickly and they are easily scratched. The striae show when you dispense with diffusers between condensers to gain speed. The diffusers can be used near the light to better advantage. The diffusion idea has been adapted in a more elegant way by frosting tungsten bulbs. Not only do diffusers at the light give more even illumination, but they avoid harshness in results and lessen the need of light distance adjustments.

Condenser Substitutes. There are very convenient parabolic mirror substitutes for condensers, for use with high power incandescent lamps. These work in connection with other cameras, or as part of a complete apparatus. With enclosed arc lamps enamel lined, hollow, rectangular pyramids called "cones" reflect light on negative through diffusers. In larger sizes, they work slower because light spreads over a larger area. The cone may be dispensed with when the powerful and convenient "M" shape Cooper Hewitt lamps are used. Simple devices of parabolic shapes like Brownie illuminators, work with fixed-focus enlargers or for lantern slides from small negatives. With the intense light from white carbons, much work is now done with flaming arcs.

Color Problems. When the enlarging light differs greatly in spectrum composition from daylight, your lens may show chemical focus. In some of the modern lights, especially the enclosed arcs, powerfully actinic rays are given out by the arc vapor shell. When the enlarging papers used are supersensitive to these particular rays, the shift of focus is intensified. The optical glass is relatively opaque to ultraviolet as is well known, and the effects must be charged to excess of violet. The thicker the condenser, the more filter action on these false rays. Rectilinears of the old types are curiously less prone to false images. There is more shift on the lesser ratios of enlargement and compensation by trial and error methods may be necessary.

Other optical troubles may come from the lens being out of center with negative; lens axis out of perpendicular with negative or easel or both; negative loose in carrier; movement of parts of apparatus during exposure; buckling of the paper; dust and moisture or greasy fingermarks on the lens. If you can arrange the negative carrier so that the emulsion of the plate side rests on the rabbet of the holder and negative goes in from the back, negatives of different thickness will register. You can use a ruled plate to test focus. This is useful on dense negatives and where prints are required of one scale of enlargement. Turning on the light constantly to find the cap or to set the diaphragm is a nuisance and outside of this, destroys your ability to judge the illumination of the image which is best when eye is dark-adapted. This condition is not restored for some moments. Do not attempt to focus through the orange safety cap.

Engineering and Construction Work. The lens problems in this field are similar to those in architecture and landscape. With field cameras, offering bellows capacity and tripod convenience, a set of convertible lenses offers flexibility in focal length. Compact hand cameras are much used for recording progress of work from day to day. These give facility in getting detail and in working from viewpoints where the use of larger cameras is not permissible, enlargements being made from selected negatives. Anastigmat equipments are almost indispensable, speed, definition and angular capacity being lens essentials in this sort of work.

Flashlight. In general flashlight and interior work, the difficulty in focusing demands a large aperture lens of the anastigmat type. It will, of course, be stopped down for depth before the exposure is made. Interior and dinner parties are often made with "banquet" cameras for plates 12 x 20 and 7 x 17 inches, which call for lenses of very large available angle for the respective diagonals of 28.3 and 18.4. For the larger size the Dagor 14-in.; Tessar or Carl Zeiss IIb, 16-in. and Turner-Reich II, 15-in. will cover satisfactorily. For the smaller size the Tessar or Carl Zeiss IIb, 10-in.; Dagor 10¾-in. or Turner-Reich 12-in. may be used. Wide Angle lenses are also used, for which see Architecture. On these banquet cameras, a swing-front is substituted for the usual swing-back movement, because of the greater need of tipping the camera downward. The advantage of an anastigmat here is found in the flat field characteristic of this type. You do not have to stop down to any smaller aperture than is requisite to give the desired depth, which often means a larger aperture and shorter exposure. Quantity of powder with a minimum of smoke nuisance result when open flashes are used.

For flashlight portraiture in the studio, with such devices as the Victor Flash Cabinet, the ordinary portrait lens will suffice for all classes of subjects. In home portrait work the lenses fitted to special home outfits or the amateur's hand camera will generally meet the requirements, the anastigmat being ideal.

Flowers. Proper perspective effects and proportion of parts are essential in this work. Focal length is therefore a prime consideration, although rapidity is also a desirable aid as flowers wilt quickly in the studio and are subject to continual movement when photographed out of doors. With short focus lenses the near parts appear much too big and more distant parts are dwarfed. Convertible lenses are most useful, the single elements offering a wide choice of focal lengths for different requirements. The camera, of course, must have ample bellows extension to accommodate the changing focal lengths used. With some flowers which present a deep cup-like formation with interior details, the device of getting a small image with a short focus anastigmat stopped down for depth and then enlarging from this negative, is necessary to properly represent the subject. With hand cameras out-of-doors, the portrait attachment or a fixed-focus telephoto of large aperture will give large images with limited camera extension. In some cases, as in making catalogue illustrations for seedsmen, where it is desired to show one part or element of a flower or bloom more prominently than the remainder of the flower, wide-angle or medium-angle lenses are deliberately used to get this disproportionate rendering of part of the flower.

Hand Cameras. Rectilinear lenses of excellent quality come on ordinary equipments. Moderate price anastigmats have become popular of late years, to meet the demand for better corner definition than the old rectilinear can give at its full aperture. Such types are the Kodak Anastigmat, F:7.7, Wollensak, Ansco Modico, Rexo and others of F:7.5 speed. Moderate speed anastigmats of F:6.3 type are the practical limits of speed, because of focus scale errors due to the limited depth of the faster types. Above F:6.3, the percentage of unsharp pictures from misjudging distance is very high. This can be overcome by using a Kodak Range Finder or Heyde Distance Meter. Faster lenses have their proper place on cameras where speed can be used efficiently, like reflecting types or on miniature cameras taking shorter focus lenses. The F:6.3 lenses figure 60 per cent more speed than rectilinears and 44 per cent above F:7.5; but when equal definition is considered, they show about double the speed of the rectilinear in practice.

The 3a sizes take lenses 6 to 7-in. focus, 2⅞ x 4⅞ and 3¼ x 4¼ need 4 to 5-in. focus in appropiate shutters with exposures in some cases running up to 1/300 second. Kodaks and Premos come with Kodak Anastigmats, F:6.3 and F:7.7, Tessar 11B, F:6.3, Protar VII F:7 and B. & L. Kodak Anastigmat, F:6.3; Ansco furnishes Ansco Anastigmats, F:6.3; Modico, F:7.5; Ica and Contessa cameras carry Carl Zeiss Ic, F:4.5; IIb, F:6.3; Dominar, F:4.5; Amatar IX, F:6.8; Hekla, F:6.8; Citonar, F:6.3; Teronar, F:5.4; Goerz cameras are fitted with Dogmar, F:4.5; Dagor, F:6.8; Tenastigmat, F:6.3; Rexo cameras have Rexo and Cooke Anastigmats, F:4.5, F:6.3, and F:7.5; Ernemann cameras are equipped with Carl Zeiss, Ernon, Ernar and Vilar anastigmats. Special lenses may, of course, be fitted to order. Hand camera lenses are often mounted more compactly for the smaller shutters used. Others come in cells threaded to go direct into standard shutters. There is no objection to using a convertible doublet when available but lack of bellows capacity usually bars out the use of single combinations.

Speed cameras of the focal plane type, without reflecting mirrors, e. g. Speed Graphics, the Palmos B, Deckrullo-Nettel and others have ample lens board room. You can fit F:4.5 lenses as on reflecting cameras. Where the camera front comes out on struts, to a fixed extension, you need special focusing mounts for lenses. Such cameras are Goerz Ango, Ica Palmos, Contessa-Nettel.

Cameras of the compact cycle types with focusing screens, like Cycle Graphic, Premo, and Ingento, have lens boards which will take large diameter F:4.5 or "soft focus" lenses. Convertibles and some telephoto lenses are practical because of the ample bellows provided by this type.

Some of the Ica, Goerz and Contessa cameras have double bellows extension in the small sizes and with choice of convertibles. Nostar and Distar used with Zeiss lenses give telephoto enlargement.

Interiors. Photography indoors is often hampered by lack of space. You cannot get back far enough to include all you wish to show, and wide-angle lenses are quite necessary. You must accept their limitations and make the best of the situation. To cope with inevitably strained perspective, experienced workers will remove objects right up under the lens and arrange others so as to break up unpleasant lines. The ground glass is the only sure test, as objects visible to the eye are often obscured to the camera. You can modify bad lines by not having the camera too high. A high position makes the floor seem to run up hill. Central viewpoints are rarely satisfactory. Swing and rising or cross front adjustments are constantly used. Tilting tripod tops are very convenient, also a ground-glass ruled in squares to check up vertical lines.

Regular wide-angles are slow. With a convertible doublet, of short focus, e. g. Dallmeyer Stigmatic, F:6, you have more light in focusing, also with rapid wide-angle types like Bausch & Lomb, Series IV and V; Primoplane, F:6.5; Protar IIIa, F:9; Wollensak III, F:9.5. The less expensive wide-angles, as Turner-Reich, Series X and Symmetrical, F:16 have advantages on certain subjects: looking down a street or into corners of rooms, where the field of lens fits field of view.

The Hypergon has special applications when its enormous angle of 135° can be utilized. With this lens or any lens over 90° angle, it is quite possible from a corner viewpoint to show all four walls of a room.

Landscapes. The problems of perspective and angle of view lead at once to convertible lens selections, e. g. Turner-Reich, F:6.8; Dallmeyer Stigmatic, F:6. Lenses you can build up into sets, like Protars and Pantars, have advantages when a limit in viewpoint is forced upon you.

Old single landscape lenses make brilliant images, and soft focus lenses find application in your pictorial work. Rectilinear lenses are used by thousands, both complete and in the single combinations, e. g. Gundlach Perigraphic and Rapid Rectigraphic.

In mountain landscapes particularly do you need long focus lenses. Contrast is hard to preserve and filters are indispensable. Telephotos find useful application where large images or distant detail is desired, e. g. Bausch & Lomb Telephoto Attachment; Gundlach Pancratic; Dallmeyer Adon, Dallon, etc.

Marines and Surf Photography. On the water or at the seashore the abundant illumination makes the choice of a lens a simple matter as single landscape lenses, rectilinears or anastigmats may be used at will. Distance plays an important part, so that long focus lenses are most often desirable, fixed-focus telephoto anastigmats and the single elements of convertibles being useful. The principle of taking it small and enlarging afterwards has special application. Mortimer's remarkable surf pictures were made with a rectilinear on 3¼ x 4¼ plates and afterwards enlarged to 20 x 30 inches. Focal lengths double the longest way of the plate give desirable proportion of parts. For nearby surf or breaking waves an anastigmat may be necessary for speed when the light is not of the best. For still work, as in harbors, filters are needed and soft-focus lenses offer pictorial advantages.

Lantern Slides. When correctly made, lantern slides by reduction have advantages in quality over the contact method. The lack of perfect contact affects sharpness. When you make slides by the camera method, the depth of focus of the projected image takes care of any irregularities of surface, and you have added facility of using any or all of the negative, and enlarging or reducing the scale.

A flat field lens saves stopping down. Slides of precise definition allow larger screen images, but no lens can hold definition not present in the original negative. The focus may be as short as 4 or 5 inches, as you figure only on covering the maximum mask opening of 2¾ x 3 in.

Miniature Cameras. Anastigmats of short focal length are usually fitted to small cameras. While relative aperture is preserved, the actual diameter of the lens becomes small enough to permit fitting to compact interlens shutters. You approach conditions of universal focus, with comparatively large stops. Quite often the light conditions permit stopping down and still further improvement of definition. The enlarging possibilities then increase tremendously. Objects in different planes are now more equally sharp, and as the image shows less contrast in sharpness, it permits a greater degree of enlargement. Larger pictures will naturally be viewed from greater distances, which again helps the situation. Motion pictures are often quoted in explanation, but the analogy is complicated by the rapid shift of images and the persistence of vision effects. Very large enlargements from motion picture films have been made to 40 x 54 inches with excellent effect. The images at close range show individual silver grains, but at suitable distances become pictures in continuous tones, suitable for large exhibition purposes. All lenses of sufficiently short focal length are fitted to miniature cameras, with maximum efficiency in anastigmats of speeds F:4.5, F:6.3. See *Hand Cameras*.

Nature Photography. Speed is the primary essential in this field, together with the large images given by long focus lenses. Frequently the work must be done under poor light conditions or from distant viewpoints, with shy and restless subjects. In some instances the camera is concealed in a "blind" where a "close-up" of the subject is desired. Such conditions call for anastigmats of large aperture and rapid fixed-focus telephotos.

Carl Akeley, in photographing African big game, made good use of the single element of a convertible anastigmat, which gave him a focal length of 24-in. sufficient for a fairly large image from distant points. The fixed-focus telephotos now available are invaluable in this sort of work. Thus the Dallon F:6.5, with a camera extension of 6 inches, gives an equivalent focal length of 15 inches, i. e. a magnification of 2½ times of the image given by the normal 6-in. lens. The Naturalists' Graflex is fitted with the B. & L. Telestigmat of 14½ inches focal length, giving an image the same size as would be obtained with a 24-in. lens.

A 17-in. lens, working on a reflecting camera which ordinarily uses an 8-in. lens, will give an image one inch high of a deer thirty-six inches high photographed at 50 feet, or 2¼ inches high if photographed at 25 feet.

Panoramic Work. For matched section panoramic views the lens should be of ample focal length, and for very accurate work the rotation point is not at the tripod socket, but under the back nodal point of the lens.

If the camera has a supplementary bed, you can adjust it to satisfy this condition, or such a bed can be improvised. Liberal overlaps are advisable because of the chance of defects at the edges of the negatives and also to allow for a true joint between the sections. The camera must be carefully levelled, so that the horizon runs true through all sections. Cirkut cameras need convertibles, the long focus single lenses being very useful. While film and camera both move, the image laid on by the slot is relatively at rest and stays sharp. Cirkut lens fittings must be made by the makers of the camera as the proper gears are determined by trial and error.

The angle of rotation determines the angle of view; you really make wide-angle views with a long focus lens. The longer the focus, the better the proportion of any figures in the group, and the distortion of long architectural lines is reduced to a minimum. Expert Cirkut operators take positions opposite one end of a building and thus avoid perspective lines running both ways. Any convertible lens is suited to this camera, but the spacing of focal lengths on the Turner-Reich Series II makes this an ideal lens for the purpose.

Panoramas 6 x 20, 7 x 17 and 5 x 12 can be made with cameras of the "banquet" type or the Gundlach Panoramic, the lens requirements being as given under *flashlight* work. The bellows capacity of these outfits is sufficient to accommodate the single combinations of some convertibles.

Photo-Micrography. Low power photo-micrography is simply direct enlargement with short focus lenses. Thus for objects requiring a magnification of 2 or 3 times only, a lens of 3-in. focal length is used, while for magnifications of 7 or 8 diameters a rectilinear lens of about 1¾ in. will serve.

Specially corrected lenses such as the Micro Tessars, with front and back cells that interchange give, with a bellows draw of 20 inches, enlargements of 15, 10 and 7 times for 32, 48 and 72 mm. foci. Spencer photographic lenses are furnished in 16, 32 and 48 mm. foci and Zeiss Apo-Planars from 20 to 100 mm.

Results in high power work depend largely on the painstaking centration of lighting and optical systems and super-rigidity of apparatus. Motion picture lenses of short focus are sometimes used because of their focusing devices e. g. the Kino Hypar, F:3.5. Elaborate photo-micro equipments are furnished by Bausch & Lomb, and Folmer & Schwing furnish apparatus designed for low power and laboratory work. Micro-photography is the reverse process, the making of very small images from large originals, such as microscopic scales for apparatus of various sorts and the pictures in the tiny opera glasses and novelties imported from abroad. In this method there is need for the same super-accurate corrections and adjustment, wide-angle lenses of short focus (1-in.) being used.

Portraiture in the Studio. Three factors control the selection of lenses for studio portraiture: focal length, rapidity and quality of definition.

Truth of drawing—the avoidance of distortion or disproportion in the features and parts of the figure, together with the ability to control the size of the image on the plate (scale), depend on the focal length of the lens used. Wherever possible, a lens of focal length twice the longest side of the plate should be used for figure portraits, with greater focal length for large heads and shorter focal length for groups. Unnatural perspectives result from yielding to the temptation of too large images with lenses of short focal length. Moderate size images, made at a proper distance with a fairly long focal length, will give more pleasing portraits and cut down the demand for resittings. The available operating distance, i. e. the length of the studio, will determine the maximum focal length which can be used. As to this point the reader is referred to the tables showing the minimum length of studio required for lenses of different focal length, which may be found in the yearbooks and some pre-war lens catalogues.

Rapidity is essential in the portrait lens to avoid the possibility of movement in the subject during the exposure, especially with children and restless sitters, and also because of the limited volume of illumination used in many studios. This has been estimated as not more than 1–500th of the bright light out of doors. The general use of powerful artificial lights in modern studios, together with the super-speed films and plates of today, may have remedied this difficulty in some measure, but a speedy lens is still a desirable studio feature.

Speed and "Depth" do not go together in lenses of large aperture over three inches focal length, but most portrait lenses working at F:4.5 give sufficient depth when handled judiciously. Fast lenses which have to be stopped down for depth are no longer fast. Roundness and relief effects are thus often sacrificed, this resulting from the loss of the large aperture peculiar to the portrait lens. As matter of fact by "depth" the portraitist means, not the "depth of focus" so much discussed by outdoor workers, but a roundness, relief and atmospheric depth which enable one to look into the picture as it were. This pseudo-relief in portraiture is the result of skillful lighting or the illumination of the subject and the use of a lens of large diameter.

The Quality of Definition desired in a portrait today is a matter about which no two professional workers can agree. Formerly it was thought essential to secure the finest possible definition in the center of the field, usually occupied by the head of the subject on the plate. In accordance with this belief the standard portrait lens, originated by Petzval, in 1840, was designed to give a brilliantly illuminated and microscopically defined image within a limited area (usually not larger than the diameter of the lens itself) at the center of the plate, and to do this with a large aperture, meaning rapidity. With portrait lenses of this type there is some curvature of field, astigmatism, distortion and a tendency to flare when small stops are employed.

Portrait Lenses of the Petzval type, improved in various features, can be obtained today from many lens makers, e. g. the Vitax F:3.8; Vesta F:5; Eastman Portrait Lenses F:4 and F:5; and Gundlach Series A. The Dallmeyer Patent Portrait Lenses, in three series, F:3, F:4 and F:6 are constructed on a different principle, and are free from many of the faults of the Petzval type.

The introduction of the modern anastigmat led many makers to design these in the larger sizes to replace the earlier types of portrait lenses, e. g. the Tessar or

Carl Zeiss Ic; Cooke F:4.5; Graf F:4.5; Heliar F:4.5; Beck Isostigmar F:5.6; Portrait Hypar F:3.5 and F.4.5, and the Aldis F:3. These are anastigmat portrait lenses and, in addition to their rapidity and critical definition, offer the advantages of flatness of field and large angular capacity, properties which are very useful in photographing full length figures and groups, where the older portrait lenses have to be stopped down.

The modern tendency in favor of diffused or soft definition in portraiture has resulted in radical changes in studio lenses. Thus the Dallmeyer Patent Portrait Lenses, the Cooke Portrait Anastigmat, the Graf Variable, the Beck Isostigmar, the Aldis and the Velostigmat mentioned above are all fitted with diffusing devices attachments giving any degree of softness of definition at will, with critical sharpness when this is desirable. Among portrait lenses specially designed to give soft-focus effects may be mentioned the Smith Visual Quality F:4.5; Verito F:4; Plastigmat F:5.6; Bishop S.F. F:6; Hyperion F:4; the Struss Pictorial F:5.5 and the first of all soft-focus lenses, viz. the Dallmeyer-Bergheim.

Large Heads should be made with a very long focus lens. Such lenses are necessarily bulky and demand ample studio length. If the available operating distance does not permit this being done direct, it is better to get it by enlargement from a small negative than to attempt to do it direct on a large plate with a short focus lens. The front element of an old lens of the Petzval type will serve this purpose very well. Remove the rear element and the hood from the front cell; put the front element in the rear cell and replace the hood in the front lens cell threads. This will double the focal length and give a very pleasing, soft definition.

Groups and Figures call for flat field lenses of large angular capacity, with speed. This means an anastigmat. Rapidity means the elimination of movement; a flat field gives better proportion of relative size among individuals in a group, and covering power means better definition and illumination out towards the edges of the plate. Long focal length is always desirable where the length of studio permits. Groups made with lenses of short focal length and wide angle have unpleasant perspectives—the penalty paid for lack of operating distance. Most of the lenses mentioned as anastigmat portrait lenses above are admirable for group work. For 8 x 10 and 11 x 14 plates the focal lengths generally used are 12 and 14 or 16 inches respectively. Other good group lenses are the Dagor F:6.8; Syntor F:6.8; Pentac F:2.9; Tessar IIb F:6.3; Graf F:6.3; Turner-Reich F:6.8; Cooke III F:6.5 and Collinear F:6.8. Of course the convertibles, Protar, Pantar, Turner-Reich and Stigmatic will be used by those who possess them.

Home Portraiture. Much of what has been said about lenses for studio work applies to portraiture in the home. But here we have to take conditions as we find them, e. g. poor lighting conditions, lack of operating distance, etc. Speed is the most necessary lens quality and 12 inches will generally mark the limit in focal length. When hand or reflex cameras are used the lenses must, of necessity, be compact and this bars out the bulky portrait lens of large diameter and generous focal length. Any anastigmat of F:6.8 or thereabouts will cover most requirements; the convertibles or sets afford variety in focal lengths useful in many cases; and the fixed-focus telephoto anastigmats, e. g. the Dallon Series XVIII F:6.5; Series XVII F:6.8; Series VI F:5.6; and Cooke Telephoto offer the advantages of long focal length (large images) with the normal camera extension. When large aperture anastigmats are used in portraiture, at home or in the studio, the use of a lens hood will vastly improve the quality of the results.

Scientific Uses. The laboratory tasks run to copying, enlarging, lantern slide making, etc. A good convertible or set is the best selection. It may be used on copying, enlarging, and reducing cameras and the special laboratory outfits or lantern slide cameras, or on the view models and compact double extension cameras intended for use both inside and outdoors. The doublets do the copying. You find the single lenses useful for flowers, minerals, etc. Short focus movie lenses or photo-micro lenses are useful for direct enlarging of very small specimens. Some of the special photomicrographic outfits are also admirably adapted to certain types of laboratory work.

Photography has innumerable applications in special photo recording devices such as electrocardigraphs, motion time study, meterological recording instruments, oscillographs, and many others. In spectrum research for transparency to ultra-violet, the optical system must be made of quartz. Astronomical work is done with large diameter lenses of the Petzval type or special anastigmats, such as Cooke Series V and Astro-Tessars. All such lenses are permanently focused by trial and error methods. Ordinary telescope lenses with filters have been successfully employed for some purposes.

Soft-Focus Lenses are so fully dealt with in The Photo-Miniature: No. 184 that we need not consider them here. See under *Portraiture*.

Stereoscopic Photography calls for no special lens requirements except that the two lenses employed should be matched in focal length and the shutter units must give identical exposures. The separation of the lens centers in American stereo practice is generally fixed at 3¼ inches in larger sizes and less in smaller sizes. European stereo outfits use a smaller separation, around 2½ inches. Stereo distortion results from too great lens separation. In scientific work the camera itself can be moved, giving absolute control of the angular separation on close-up positions.

Supplementaries. These are extra or auxiliary low-power lenses which, added immediately in front of the regular lens on the camera, serve to alter its focal length to meet special requirements. Thus the addition of a thin positive (convex) auxiliary shortens, while a negative (concave) auxiliary lengthens the focal length of the lens with which it is used. They were first introduced for use with fixed-focus hand cameras, as an inexpensive device enabling the user to obtain pictures of objects nearer the camera than was possible before with cameras of that type. Today they are available for use with both fixed-focus and focuing cameras, for making sharply-focused (large) images of nearby objects or "close-ups" of any description, e. g. the familiar Kodak Portrait Attachment, and are sometimes sold in sets for amateur copying, "wide-angle" work and the like, with cameras having limited bellows extension.

This does not mean, however, that supplementaries are in any sense equivalent to the highly corrected single elements of lenses of the convertible type, or that they can be used in the same way. While so constructed that they do not materially interfere with the normal qualities of the lenses with which they are used, they cannot be expected to equal the performance of the regular, corrected lens. Generally there is a softening or diffusion of definition, with a lowering of efficiency, hardly noticeable or detrimental in the kinds of work for which supplementaries are employed.

In practice the maximum efficiency is secured with auxiliaries designed and adjusted for use with specified lens equipments. But ordinary uncorrected spectacle lenses can and have been adapted as auxiliaries, especially in pictorial or "soft-focus" work. A noteworthy achievement in this field is the Wolfe Artistic Lens, a very thin auxiliary lens of zero focus (no power), in the manufacture of which a special variety of glass and carefully computed curves are employed. In use it is simply slipped on in front of the anastigmat or rectilinear with which the camera is equipped, and gives, without alteration of focal length or size of image, the most desirable "soft-focus" effects.

A Novel Use of the Portrait Attachment, as a means of *increasing* instead of reducing the focal length of a lens, was described by Kendrick Chamberlain in *American Photography* a few years ago, and is worth noting by readers interested in home portraiture. I abbreviate Mr. Chamberlain's description. Using a 5 x 7 camera fitted with a symmetrical R. R. lens of 8 inches focal length in home portraiture, the familiar trouble of distorted or violent perspectives was encountered, due to the use of a lens of such short focal length and working too close to the subject. Having ample camera extension, he attempted to remedy the difficulty by using one of the halves of the complete symmetrical, as a separate lens of about 17 inches focal length. This however, was generally impracticable, the room of ordinary dimensions rarely permitting of the necessarily increased distance between camera and subject required by a lens of this focal length. Removing the rear element of the symmetrical, he slipped a Portrait Attachment of suitable size over the front of his lens, and thereby shortened its focal length to 11 inches. This combination proved wholly successful. The gain in focal length, as compared with that of the complete symmetrical, although falling well within the "operating distance" of the average room, was sufficient to eliminate the violent perspectives before inevitable, and allowed greater freedom in the pose or arrangement of the subject. Incidentally, the addition of the attachment automatically softened or suppressed the somewhat wiry detail given by the symmetrical, thus enhancing the pictorial quality of the work.

Telephotography. The bellows extension necessary for long focus lenses goes beyond practical limits on larger sizes. In the telephoto, like a field glass, you have a positive objective with a concave negative lens, set at so-called telescopic condition. A real image is formed on the ground glass in size equivalent to that of a long focus lens, but with a much shorter back focus or camera extension. Telephoto enlargement has some advantage over ordinary methods in which the granularity of negative image is magnified proportional to enlargement ratio.

Such devices, known as telephoto attachments, are mounted in a tube with adjustable separation and a scale of magnifications on the tube. Together with the regular lens used, they form a telephoto system. The regular lens and the attachment lens are for brevity called telepositive and telenegative. The actual magnification obtained depends on relation of their focal lengths and separation. The angle covered being constant, the low power images do not fill the area covered by positive lens. On high powers, they surpass the positive lens. Full covering power is reached at three or four powers, unless low power telenegatives are used. Magnification times focus of the positive gives the equivalent focus of system, and magnification times the stop number gives the telephoto stop value. Exposures can be figured by telephoto system stop values, but it is customary to note the exposure for the positive lens under ordinary conditions and multiply this by the square of the magnification. A lens of F:6.8, 7 inch focus, at 3 magnifications becomes 21 inch, F:20.4. At 8 times, it is a 56 inch, F:54.4. At 5 powers, with a landscape ordinarily taking 1/5th second, F:32, you would open up to F:8 to gain speed, giving 1/20th, and multiply by 5-x 5, an exposure of 1¼ seconds. You must of course allow for the filter used, and your original exposure must be figured on the part of the landscape which is shown in the magnified image, otherwise you may join the criticism of the rule by skeptics who apply it wrongly. In tele-exposures, you are not concerned with deep shadows of foregrounds which are not included.

In focusing, you set the lens to the magnification required and get fine adjustment by slight change in separation. Moderate speed highly corrected lenses like the Dagor or Protar VIIa are preferable to ultraspeed lenses for the telepositives. Bausch & Lomb tele-attachments range from 3 to 8 magnifications, Goerz types 3 to 9, and there are similar offerings by Dallmeyer, who was the pioneer, Zeiss, Voigtlander, Ross, and others.

Grandacs are complete systems using same tele-positive, 10 in. F:4, which will also work alone. With No. 1, it gives magnifications 2¼ to 4, on 3¼ x 4¼, with 6 to 12-in. bellows, maximum speed F:10. No. 2 is for 5 x 7, and ranges 3 to 5 powers, maximum speed F:11. Gundlach Pancratic telephoto is an inexpensive complete system giving 3 to 8 powers. It substitutes for ordinary lenses in standard opening shutters on hand cameras. Tele-Peconar, F:5, works complete at 3–5 magnifications, or can be used with back lenses of symmetrical types or as a lens for large portraits.

The Adon is complete, with 4½ in. front lens and negative of 2 in. giving variable magnifications from two times up, and, at same bellows as ordinary lens, a triple enlargement.

Very low powers are more conveniently produced by the single convertibles or by supplementaries like Distar or by substitution elements of the Aldis Duo and Trio type, mentioned under convertibles. For fast work, the fixed-focus one-magnification lenses next described are necessary. By dispensing with variable magnifications, higher correction and speed can be attained. The first introduced was the Zeiss Magnar F:10, focal length 18 in. and back focus only 6 in. Busch Bis-Telar, F:9 and F:7, and Cooke Telar, F:7, work similarly, but with back focus one-half of equivalent. Other typical lenses are Telecentric, F:5.4 and F:6.8; Large Adon XI, F:4.5, Dallon Anastigmat Telephoto VI, F:5.6, and XVI, F:7.7. the last one compact enough for shutters on hand cameras. The Telestigmat, F:6.8, gives like others of this class, an image double the size of ordinary lenses which just focus in the same bellows.

Wide Angle Lenses are necessary evils. They are of short focus in proportion to the base line of the negative and never should be used where longer focus lenses will also work.

Precise anastigmats like Protar V, F:18, give extreme angles. Somewhat less angle, but greater speed comes with Protar IV, F:12.5. Other lenses are Collinear IV, F:12.5, Ross W. A. Anastigmat, F:16. The Goerz Hypergon, giving 135° angle, handles almost impossible interior or architectural conditions. A revolving star diaphragm is used to equalize illumination.

All lenses with reserve covering power are potential wide angles. You can use the Goerz Dagor up to 90° angle and have wonderful convenience of focusing with large aperture and lots of light. Protar VIIa and others can be used. Some large aperture lenses are made primarily for wide-angle work e. g. the Cooke Primoplane, F:6.5; Velostigmat III, F:9 and Zeiss IIIa, F:9.

CHESTER F. STILES

Books

Of the many useful and profitable books dealing with photographic lenses published during the last twenty years, only two or three are in print and available. These are:

OPTICS FOR PHOTOGRAPHERS. By Hans Harting. Translated by Frank R. Fraprie. 1918. 224 pages, with diagrams. $2.50

A TREATISE ON PHOTOGRAPHIC OPTICS. By R. S. Cole. 1900. 325 pages, diagrams. $2.00.

How to Choose and Use a Lens. (Practical Photography Series.) 83 pages. Paper, 50 cents; Cloth, $1.00.

Soft Focus Effects in Photography. (The Photo-Miniature Series, No. 184.) 1921. Paper covers, 40 cents.

Telephotography. By C. F. Lan-Davis. Second Edition, 1921. 112 pages, illustrated. Cloth, $2.00.

Modern Telephotography. By Captain Owen Wheeler. 1910. 80 pages. Paper covers, $1.00.

Out of print books, which may be seen at some of the larger libraries, are: "The Lens" by Bolas and Brown; "A First Book of the Lens" by C. W. Piper; "The Optics of Photography" by J. Traill Taylor; "Photographic Optics" by O. Lummer; and "Elementary Tele-Photography" by E. Marriage.

Notes

An Ingenious Depth of Focus Chart, which completely solves the "depth of focus" problem for any lens at any given aperture and object-distance, has been prepared by H. W. Lee, of Taylor, Taylor & Hobson, Ltd., the makers of the well-known Cooke Lenses (American Agents: Burke & James, Ltd., Chicago and New York).

This chart, which will prove invaluable to photographers, consists of two diagrams: Fig. 1, on which are plotted vertical and horizontal lines representing various focal lengths and object-distances, and Fig. 2, a transparent film with radial lines representing the lens apertures (F: and U. S. systems) in common use. By placing Fig. 2 in position over Fig. 1, the depth of field with any lens and stop may be found at a glance.

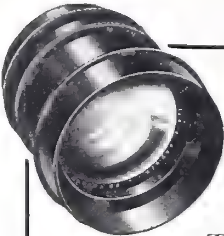
By the aid of this chart the photographer can make a Table of Hyperfocal Distances and Depth of Field for his lens or lenses within a few minutes. A supply of printed blanks, vest-pocket size, is included with the chart, which can be obtained from Burke & James, Inc., for the nominal sum of 25 cents.

A New Eastman Portrait Diffusion Disk has been added to the existing series: No. 0 for lenses of from 2 to

3¼ inches in diameter. In this size the E. P. D. D. is available for use with many lenses now used for enlarging, and for this use will be found more efficient than chiffon and similar devices since it does not increase the exposure. Another Eastman lens introduction is the Kodak Anastigmat F:4.5 in two new sizes, viz. 10 and 12 inches focal length respectively, especially useful in home portrait work.

Dallmeyer Lenses in America. I note with pleasure that the justly celebrated Dallmeyer lenses are being prominently displayed by many dealers—a welcome post-war revival. The new Dallmeyer catalogue describes and illustrates many desirable additions to the oldtime favorites, among which may be mentioned the New Large Adon, a fixed-focus telephoto lens with the remarkable aperture of F:4.5, for reflex and focal-plane cameras; two new sizes of the Dallon Anastigmat Telephotos for folding hand cameras of short bellows extension, working at F:6.5 and F:6.8; the Perfac, F:6.3 a moderate price unsymmetrical anastigmat for single extension hand cameras; the Serrac, F:4.5, and the Pentac, an anastigmat with an aperture of F:2.9, with which an adjustable diffusion device is supplied in the larger sizes.

An interesting report on "The Manufacture of Optical Glass and of Optical Systems" in America has been issued by the Government Printing Office, Washington, as Ordnance Department Document No. 2037, price 75 cents. Readers not already satiated with the lens information given in this issue of The Photo-Miniature will find useful "supplementary reading" in this report.



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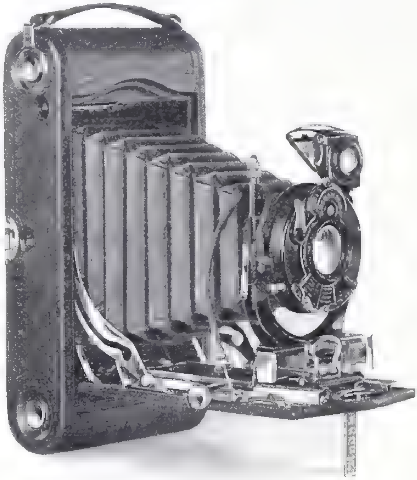

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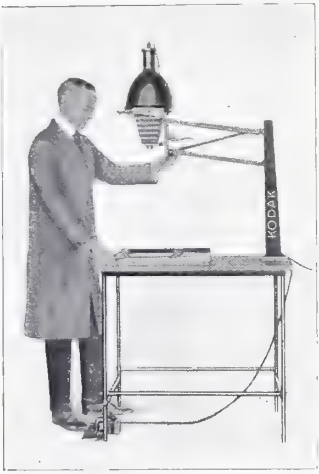

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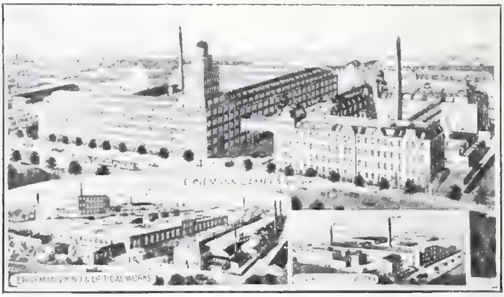

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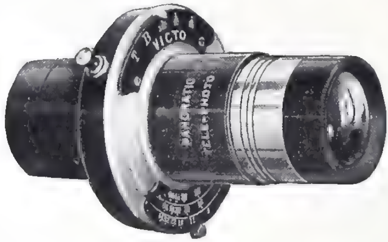

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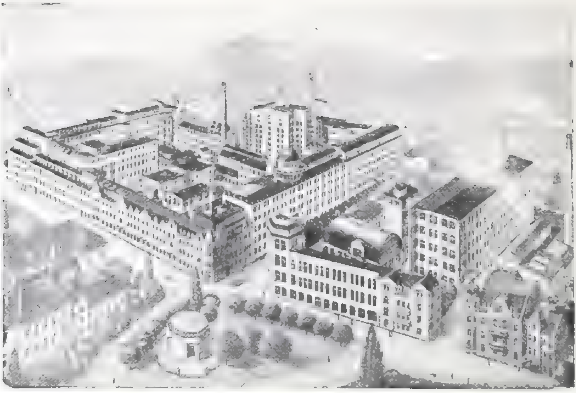

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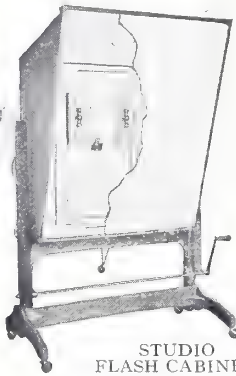

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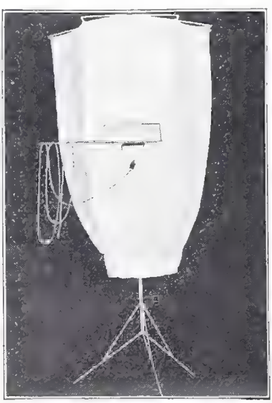

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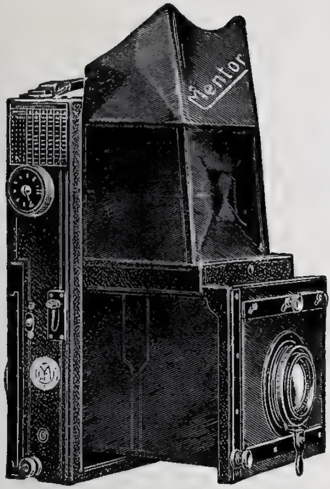

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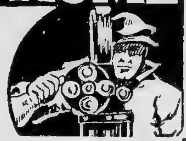

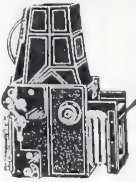

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